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TOADS (*BUFO BOREAS* BAIRD & GIRARD) OBTAIN NO CALORIES FROM INGESTED *SPHENOPHORUS PHOENICIENSIS* CHITTENDEN (COLEOPTERA: CURCULIONIDAE)

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Abstract.—Ninety percent (865/962) of the billbugs (*Sphenophorus* spp.) in 145 toad (*Bufo boreas* Baird & Girard) fecal pellets were egested alive. Dead billbugs (*S. phoeniciensis* Chittenden) found intact in toad fecal pellets have an average weight and caloric content that was 1.4% (0.13/9.06 mg) and 4.5% (0.225/5.049 kcal) *greater,* respectively, than that found for non-egested billbugs. Toads (*B. boreas*) derive no calories from billbugs (*S. phoeniciensis*) that pass intact through the digestive tract.

Key Words.—Insecta, *Bufo boreas, Sphenophorus phoeniciensis, Sphenophorus venatus vestitus,* Curculionidae, weevils, billbugs, toads, fecal pellets, survival

Beetles (Coleoptera) constitute a major portion of the diet of western toads (*Bufo boreas* Baird & Girard) (Barrentine 1991b). However, some beetles (Curculionidae: *Sphenophorus* spp.) can resist digestion, pass through the digestive tract of the toad and emerge alive from fecal pellets (Barrentine 1991a, Barrentine & Seeno 1988, Fair 1969). Although longevity is reduced for egested billbugs, some individuals (*S. phoeniciensis* Chittenden) can live three weeks post-egestion (Barrentine 1991c). Moreover, some individuals can survive three trips through the digestive tract of the toad (Barrentine in press).

Not all billbugs survive digestion by toads. Barrentine (1991a) found that 32% (1428/4406) of egested *Sphenophorus* spp. failed to emerge from fecal pellets within four days. Because nearly all of these dead billbugs were intact (fully articulated), it was suggested that toads may derive little, if any, nutrition from ingested billbugs. Further, it was hypothesized that because egested billbugs were rarely disarticulated by digestive processes, billbug mortality may be due to post-egestive causes (i.e., death may result from an inability to escape entombment from a desiccating pellet).

This study reports: (1) that 90% of the billbugs (*Sphenophorus* spp.) found in the fecal pellets of the toad (*B. boreas*) are egested alive, and (2) that toads (*B. boreas*) obtain no calories from billbugs (*S. phoeniciensis*) that pass intact through the digestive tract.

METHODS

Survival.—Freshly egested fecal pellets were obtained from western toads foraging from a fenced, 0.06 ha residential lawn [cultivar of *Cynodon dactylon* (L.) Pers. × *C. transvaalensis* Burtt-Davy 'Tifgreen'] in Bakersfield, California. Pellets were collected daily from the turfgrass surface, in the evening (21:00–23:00 h) or early morning (05:00–08:00 h), from mid-August to early September 1988, early April to mid-July 1989, and July 1991. Individual pellets were immediately rinsed

Table 1. Weight (mg) and caloric content (kcal) for egested and non-egested *Sphenophorus phoeniciensis.*

	No. samples	No. billbugs (*n*)	Total dry weight of samples (mg)	Individual dry weight, $\bar{x}$ + SD (mg/n)	Total caloric content of samples (kcal)	Caloric content, $\bar{x}$ + SD (kcal/g)	Individual caloric content, $\bar{x}$ + SD (kcal/n)
Egested	3	153	1405.7	9.19 + 0.12	7.415	5.274 + 0.031	0.0485 + 0.002
Non-egested	3	222	2010.8	9.06 + 0.06	10.152	5.049 + 0.039	0.0457 + 0.001

with water and egested billbugs (*S. phoeniciensis* and *S. venatus vestitus* Chittenden) were collected on a 1 mm mesh screen. These were transferred to vials and dried for 24 h at 24–28° C and 35–45% RH. Vials were examined twice daily and live billbugs were removed and tallied.

Calorimetry.—Live billbugs, *S. phoeniciensis,* were collected by hand from infested turfgrass (between 21:00–23:00 h), immediately frozen, and then oven dried at 68° C to constant weight (± 0.1 mg). Samples of dead billbugs (i.e., fully articulated *S. phoeniciensis* that failed to emerge alive from fecal pellets) were obtained from fecal samples preserved from an earlier study (see Barrentine 1991a). These billbugs, preserved by freezing, were washed and then oven dried to constant weight, as described above. Caloric content (kcal/g) for non-egested and egested *S. phoeniciensis* was determined with a Parr oxygen bomb calorimeter (see Dimmitt & Ruibal 1980). Weight and caloric content of *S. venatus vestitus* is not reported here because sample sizes were too small for reliable calorimetric analysis.

Results and Discussion

Survival.—A total of 962 billbugs (*S. phoeniciensis* and *S. venatus vestitus*) were isolated from 145 toad pellets. Of these, 90% (865/962) were egested alive in pellets. This survival frequency, significantly higher ($\chi^2 = 192.44$, df = 1, $P < 0.001$) than that reported in an earlier study (Barrentine 1991a), lends support for the hypothesis that egested billbug mortality may be increased by an inability to escape entombment from desiccating fecal pellets. In the earlier study, survival was determined by counting the number of billbugs that emerged from fecal pellets. In the present study, survival was not predicated on an ability to emerge from fecal pellets because billbugs were removed from fecal pellets.

Calorimetry.—The weight and caloric content for egested and non-egested *S. phoeniciensis* are shown in Table 1. Dead egested billbugs have an average weight and caloric content that is 1.4% (0.13/9.06 mg) and 4.5% (0.225/5.049 kcal/g) *greater,* respectively, than that found for non-egested billbugs. That the caloric content for egested billbugs should exceed that found for non-egested billbugs was unexpected. It may be possible that greater weight and caloric content of egested billbugs is due to exogenous organic debris (i.e., mucoid intestinal secretions with a high lipid content and undigested chitinous fragments from other arthropods) that may have adhered to egested billbugs. Exogenous lipid would be difficult to remove with water and would inflate the caloric content for egested billbugs.

Conclusion

Ninety percent of billbugs (*Sphenophorus* spp.) egested by toads (*B. boreas*) are egested alive in fecal pellets. The survival frequency for egested billbugs is mark-

edly higher than that reported in other studies. Weight and calorimetric data indicate that billbugs (*S. phoeniciensis*) found dead and intact in toad fecal pellets show no evidence of digestion. Toads (*B. boreas*) obtain no calories from billbugs (*S. phoeniciensis*) that pass intact through the digestive tract.

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